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PATENT SPECIFICATION

NO DRAWINGS

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COMPLETE SPECIFICATION

Armour Plate

We, FELDMUHLE AKTIENGESELLSCHAFT, a German Company of Postfach 240, Gladbacher Strasse, 189, 406 Viersen, Germany, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to armour plate, that is to say, a plate of projectile resistant material, for protecting military vehicles, installations and weapons against the impact of shells. The armour plate of the invention is especially applicable to armoured vehicles for repelling armour piercing weapons.

To protect them against shells and splinters, vehicles, guns and military installations are provided, as is known, with armour plating generally consisting of high grade kinds of steel. An essential disadvantage of such armour plating is its considerable weight. In the case of mobile objects, for example, vehicles, guns and naval units their mobility, speed and cruising radius is thereby substantially impaired; this is a disadvantage that cannot be made good by using especially powerful engines or the like to a satisfactory degree, because such engines require large fuel tanks. Accordingly, it has been endeavoured to deflect projectiles having a relatively flat trajectory by providing special structural expedients, for example, by eliminating vertically disposed panels and inclining the front walls of, for example, gun emplacements and the walls of turrets.

However, the aforementioned structural expedients do not offer sufficient protection from the latest armour piercing weapons whose projectiles hit the armour plating at a moderate impact velocity and by this impact ignite a funnel shaped charge of a brisant explosive, which, by virtue of its funnel shaped or parabolic arrangement, acts predominantly as a strongly directed shock wave out of the opening of the charge. During this process a copper or brass shell which screens off the charge inwardly is deformed into a plug which is ejected at a muzzle velocity of about 10,000 metres/second and this considerable velocity, combined with the high specific gravity of the shell material, enables the projectile to pierce armour plating consisting of steel 20 cm or more thick.

It is an object of the present invention to provide an armour plate giving increased protection against these latest armour piercing weapons. This protection is achieved without impairing the mobility, speed or cruising radius of armour plated units. This is mainly achieved by using a structural element other than steel, which is capable of slowing down and checking a projectile travelling with great energy in a definite direction, the new material being distinguished above all by its reduced weight.

The present invention is based on the observation that a substantially improved protection, especially against the type of armour piercing weapons described hereinbefore, is achieved by using armour plates including an energy absorbing layer comprising a plurality of particles of a non-ductile sintered refractory material bonded together in a matrix of a material that is softer than the sintered refractory material, in such a way that a section taken through the thickness of the plate will pass through a plurality of interfaces between the sintered material and the matrix.

Preferably, a major proportion of the boundary surfaces between the sintered material and the matrix include an angle other than 0° or 90° with the outer surfaces

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of the armour plate and therefore the particles of sintered material are advantageously of spherical or polyhedric shape.

Advantageously, the diameter of the particles of sintered material should be 0.5 to 5 times the diameter of the hole generally made by shells in a steel plate. Since the holes made by the conventional shell-firing weapons generally exceed 10 mm diameter, the sintered material particles should advantageously have an average diameter ranging from 5 to 50, preferably from 10 to 30, mm.

The unexpectedly greater protection afforded by the armour plates of the invention is probably due to the fact that the plug must perform a great deal of work to overcome the recurring transitions between the sintered material and the matrix and that the ever changing angles which the individual particles of sintered material make with the striking direction of the plug keep deflecting it further from its direction of attack. It has further been established that, probably owing to the deflection of the plug travelling at a high speed the plug is additionally partially split. The resultant increase in work done in passing through the plate causes a certain loss of energy so that the plug will stop in the plate much sooner than was the case with the previously used steel armour plates, having regard to the mass involved.

Sintered materials suitable for use in the present invention are advantageously those which have a hardness, on the Moh scale, of at least 7 and preferably of about 9 and are non-ductile materials which do not turn plastic even under high pressures and at high temperatures and which have a substantially higher melting or softening temperature other than steel. Such sintered minerals are sintered alumina or other high-melting oxides, nitrides and carbides, for example, magnesium oxide or silicon carbide. The suitability of the sinter bodies for use in the present invention is probably due to the fact that these sinter bodies as such are not homogeneous and, owing to their microcrystalline configuration, contain a large number of boundary surfaces of different direction and arrangement, all of which help to reduce the thrust of the plug.

As softer materials, which serve to bind the sintered material particles, it is of advantage to use synthetic resins. Such binding is necessary because if it were omitted the particles of sintered material would be forced apart by the thrust of the plug so that they could not satisfactorily perform their function.

Especially suitable synthetic resins are firmly adhering casting resins that can be cured to leave them hard and impact-resistant without being brittle. For this purpose it is especially advantageous to use epoxide resins or phenol resins which are preferably further reinforced by mineral ingredients, for example, feldspar, glass fibre or natural or synthetic fibres. Especially good results are obtained with epoxy resins, which can be modified in a wide variety of ways so as to adapt them to the sintered material concerned and have excellent adhesion to the sintered materials.

It is also of advantage to add to the synthetic resin used flame-inhibitors, for example, antimony oxide or organic chlorine or bromine compounds. Another useful measure aiming at reducing the flammability of the synthetic resins is to use synthetic materials that contain sufficient chemically bound chlorine or bromine to render them non-flammable. Such resins are, for example, the reaction products of a halogenated bisphenol and epichlorhydrin. Furthermore, there are suitable those synthetic resins which contain, for example, SO_2 groups or phosphorus compounds which render them flame-resistant, for example epoxy resins that have been cured with sulphonamides or a phosphorus containing acid.

According to another advantageous variant of the invention there are added to the synthetic resins substances that are impede the passage of energy-rich rays, for example, gamma rays and neutrons so that the armour plate affords additional protection, for example against radioactivity. Since such additives, for example lead powder or lead compounds, increase the weight of the material, they are especially suitable for incorporation in armour plates for stationary units and vehicles for which safety is of greater importance than speed, mobility and cruising range, for example for command tanks.

It is of special advantage to impede the passage of neutrons through the armour plate of the invention by using as the sintered material a sintered boron carbide. When sintered boron carbide is used the weight of the armour plate, compared with an armour plate manufactured with the use of sintered corundum, is substantially reduced and at the same time, due to the high melting point and the great hardness of sintered boron carbide, the resistance against the penetration of a projectile is increased. Another material that offers a considerable absorption resistance is cadmium.

A favourable variant of the armour plate of the invention consists in using a mixture of sintered materials of different composition, different shape and different particle size since by a suitable choice of materials the properties of the armour plate can be widely varied. Thus, for example, the density of the location of the sintered material particles can be substantially increased by using sintered material particles of various orders of magnitude.

It is an important advantage of the armour plate of the invention that its weight is far below that of conventional armour plates of high-alloy steel for an equal degree of resist-

ance to shell penetration so that for an equal protection of a unit provided with the new armour plating the unit has a greater cruising radius and greater speed and mobility. When armour plates according to the invention having same weight as the known steel armour plates are used, a substantially greater and better protection is achieved. The latter advantage is of especial importance for stationary units, for example, gun emplacements.

Numerically, the above-mentioned relationships can be expressed by the following simple formula

$$\frac{S_{Fe} \times D_{Fe}}{S_x \times D_x} = f$$

where S_{Fe} is the depth of penetration of a certain charge in steel; S_x is the depth of penetration of an identical charge in the material to be compared; D_{Fe} is the specific gravity of steel; D_x is the specific gravity of the material to be compared or the average specific gravity when heterogeneous materials, for example, laminated materials, are concerned; and f is the factor which indicates by how much a material is better or worse than steel.

When f is greater than 1, the material under test is superior to the conventional steel armour plates. As will be shown in the following Examples it is possible to increase the protection afforded by the armour plate of the invention by at least 100% compared with the previously used armour plates.

Moreover, compared with steel the armour plates of the invention have the advantage that they can be nonmagnetic so that limpet charges, for example those used in sea warfare, cannot be attached to them. Furthermore, the heat conductivity is much less so that, for example, a tank has, in spite of its engine heat, roughly the same temperature as its surroundings so that the infra-red scopes of modern armour piercing weapons cannot, or can only with difficulty, spot it while travelling at attacking at night.

For structural reasons the armour plate of the invention will, in general, be lined on both sides with a covering layer, which may be, for example, conventional steel plate, especially when used on mobile units, so that a laminated structure results. These laminated panels give the whole structure a special stability and take over, for example in a tank, the function of supporting the turret, the weapons and the chassis and protect them from small arms fire and splinters. However, this external steel skin makes up only a fraction of the hitherto used total thickness. The improved protection obtained by this invention makes it unnecessary to use steel as an inner lining and advantageously, the inner lining is a light alloy or one of the recently developed non-metallic laminates so that in this manner too further weight is saved.

The inner and the outer coverings may alternately be made from light materials and in this case, it is of advantage to add to the outer lining finely ground hard materials, for example, corundum, bonded with an epoxy resin. In this manner the outer covering is made more resistant and affords sufficient protection against small arms fire.

The novel armour plates are also of considerable importance in increasing the protection given to installations and mobile units armour plated in the conventional manner against armour piercing projectiles. *Inter alia*, the armour plate of the invention may be added, for example, in especially vulnerable zones as an additional external protection, or on the inside of lightly armoured units, and in this manner it may afford additional protection, especially against limpet shells when it is non-magnetic.

The following Examples illustrate the invention. The casting resins used in the Examples are commercially available epoxide resins prepared from bisphenol A and epichlorhydrin and are cured and modified by the addition of a polyamide prepared by the condensation of a di- or trimeric unsaturated, long-chain fatty acid with a low molecular weight polyamine, that is to say, a polyamide sold under the Trade Mark "Versamide". The hardness of the cured resin depends on the amount of "Versamide" that is added and the consequent degree of cross-linking of the cured epoxide resin.

Example 1

A piece of steel tubing of 100mm length was closed at one end by welding on a steel sheet 5mm thick, and was then filled with globules of sintered, extremely finely ground high-grade corundum. The interstices were filled with a casting resin. The other end of the cylinder was then closed with a steel sheet 7mm thick and the cylinder was shot at. Various cylinders were made up in this way and the following results were obtained:

(a) Globule diameter 6 to 7 mm

Resin: a soft epoxide resin

$$S_{Fe} = 60 \text{ mm}, \quad D_{Fe} = 7.86 \qquad \frac{S_{Fe} \times D_{Fe}}{S_x \times D_x} = f = 1.14$$
$$S_x = 107 \text{ mm}, \quad D_x = 3.14$$

(b) Globule diameter 4 to 7mm
Resin: A medium hard epoxide resin

$$S_{Fe}= 60\text{ mm},\quad D_{Fe}=7.86\quad S_x = 96\text{ mm},\quad D_x=3.14\quad \frac{S_{Fe}\times D_{Fe}}{S_x\times D_x}=f=1.57$$

(c) Globule diameter 12mm
Resin: same as under (b) above

$$S_{Fe}= 60\text{ mm},\quad D_{Fe}=7.86\quad S_x = 88\text{ mm},\quad D_x=3.14\quad \frac{S_{Fe}\times D_{Fe}}{S_x\times D_x}=f=1.71$$

(d) Globule diameter 12 mm
Resin: A hard, thermostable epoxide resin

$$S_{Fe}= 60\text{ mm},\quad D_{Fe}=7.86\quad S_x = 86\text{ mm},\quad D_x=3.14\quad \frac{S_{Fe}\times D_{Fe}}{S_x\times D_x}=f=1.75$$

EXAMPLE 2

Steel tubes of 170mm outside diameter and 170 mm in length were provided with a bottom by welding on sheet steel 30 mm thick. The resulting pots were filled with sintered corundum globules and potted with a casting resin. The other ends of the tubes were then closed by welding on steel lids 20mm thick.

These tubes were fired on with shells containing 56 g of explosive. To increase the penetrating power (focussing) of the charges they were electrically detonated at a distance of about 100m from the target. In no case was penetration observed.

Since owing to the hardness of the charge the blocks could not be separated or cut open, X-rays diagrams were made of the target blocks. To obtain a contrast the shot channel was filled with lead powder

2(a) Globule diameter 22 to 23 mm
Resin: a medium hard epoxide resin, which is stable up to 130°C

$$S_{Fe}=132\text{mm (tool steel)},\quad D_{Fe}=7.86\quad S_x=146\text{mm}\quad D_x=3.9\quad \frac{S_{Fe}\times D_{Fe}}{S_x\times D_x}=f=1.81$$

2(b) Globule diameter 11 to 12 mm
Resin: As in Example 2(a)

$$S_{Fe}=132\text{mm},\quad D_{Fe}=7.86\quad S_x=161\text{mm},\quad D_x=3.9\quad \frac{S_{Fe}\times D_{Fe}}{S_x\times D_x}=f=1.64$$

2(c) Globule diameter:

abt. 6cm layer, globules of 22—23 mm dia.
„ 6cm „ „ „ 11—12 mm „
„ 6cm „ „ „ 22—23 mm „

Resin: As in Example 2(a)

$$S_{Fe}=132\text{mm},\quad D_{Fe}=7.86\quad S_x=130\text{mm},\quad D_x=3.9\quad \frac{S_{Fe}\times D_{Fe}}{S_x\times D_x}=f=2.03$$

WHAT WE CLAIM IS:—

1. An armour plate (as hereinbefore defined) comprising an energy absorbing layer which comprises a plurality of particles of a sintered refractory material bonded together in a matrix of a material that is softer than the sintered material in such a way that a section taken through the thickness of the plate will pass through a plurality of interfaces between the sintered material and the matrix.

2. An armour plate as claimed in claim 1, wherein a major proportion of the boundary surfaces between the sintered material and the matrix inside the armour plate includes an angle other than 0°C or 90°C with the outer surfaces of the armour plate.

3. An armour plate as claimed in claim 1 or claim 2, wherein the particles of sintered material are of spherical or polyhedric shape.

4. An armour plate as claimed in any one

of claims 1 to 3, wherein the sintered material has an average particle size ranging from 5 to 50mm.

5. An armour plate as claimed in claim 4, wherein the sintered material has an average particle size ranging from 10 to 30mm.

6. An armour plate as claimed in any one of claims 1 to 5, containing a mixture of sintered materials having different compositions, shapes and/or particle sizes.

7. An armour plate as claimed in any one of claims 1 to 6, wherein the sintered material or part thereof is a material that offers a large absorption reaction cross-section to radioactive irradiation.

8. An armour plate as claimed in any one of claims 1 to 7, wherein the softer material is a synthetic resin.

9. An armour plate as claimed in claim 8, wherein the synthetic resin is tacky, castable synthetic resin that can be cured to form a hard material that has considerable impact strength but is not brittle.

10. An armour plate as claimed in claim 8 or claim 9, wherein the synthetic resin is as such a flame-inhibitor or contains a flame-inhibitor.

11. An armour plate as claimed in any one of claims 8 to 10, wherein the synthetic resin is further mixed with substances that impede the passage of radioactive or other energy-rich rays.

12. An armour plate as claimed in any one of claims 1 to 11, wherein the energy absorbing layer is provided with external covering layers so that a laminated structure results.

13. An armour plate as claimed in claim 12, wherein the covering layers are parallel to one another.

14. An armour plate as claimed in any one of claims 1 to 13, characterised in that it is nonmagnetic.

15. An armour plate as claimed in claim 13 or claim 14, wherein the covering layers consist of light structural materials, and ground hard materials are incorporated in the covering layer on one surface.

16. An armour plate as claimed in claim 13, wherein the energy absorbing layer is covered on one surface by a layer of steel and on its other surface by a layer of alight structural material.

17. An armour plate as claimed in any one of claims 1 to 16, wherein the sintered material is sintered alumina, sintered silicon carbide, sintered boron carbide or sintered magnesium oxide.

18. An armour plate as claimed in claim 1, substantially as described in Example 1 or Example 2 herein.

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